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MULTI VARIABLE OPTIMIZATION OF SURFACE GRINDING PROCESS USING GENETIC ALGORITHM

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ABSTRACT

In the present study, an attempt was made to optimize the 'Surface Grinding' process by following one of the recent optimizing techniques 'Genetic Algorithm'. Due to random variation in variable constraints the surface finish is altering in the surface grinding operation which is an adverse effect. So, we tried to get the values for variable constraints, which satisfy both minimization of production cost and maximizations of production rate with the excellent surface finish. For this, we considered variable constraints as workpiece speed, wheel speed, crossfeed rate and down feed rate. To carry out this work we have selected Al2O3 as our grinding wheel, abrasive according to grinding wheel specification (A 45 K 5 V). And workpiece as stainless steel because it is resistant to corrosion and staining, low maintenance and familiar luster make it an ideal material for many applications. We used 'C' language compiler as our programming platform. Initially, we performed a surface grinding operation for 6 Stainless steel workpieces with Aluminum Oxide abrasive, by taking the optimum variables from GA, we again performed surface grinding for one more component which gave us better surface finish than previous.

KEYWORDS: Surface Grinding, Aluminum Oxide Abrasive, Genetic Algorithm, Surface Finish & Stainless Steel

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Original Article

INTRODUCTION

Grinding is the process of removing material by the application of abrasives which are bonded to form a rotating wheel. When the moving abrasive particles contact the workpiece, they act as tiny cutting tools, each particle cutting a tiny chip from the workpiece. The grinding process provides high accuracy and excellent surface finish. Surface grinding is normally used to grind plain flat surfaces. Workpiece surfaces produced by grinding are influenced by the following factors:

- Workpiece material – harder materials allow finer finishes.
- At high temperatures - the material tends to become weakened and is more inclined to corrode.
- Type of wheel – fine grain yields finer finishes.
- Dressing procedure – improperly dressed wheels will mark the work surface.
- Feed rate – finer finishes are obtained with slower feed rates.
- Machine rigidity – order, worn machines yield a poor quality finish.
- Lubricant cleanliness – coolant filtration removes waste that could damage the workpiece surface.

Work Piece Selection

In this project, the Surface Grinding operation was performed on the stainless steel workpieces. Steel is an alloy of iron with carbon 0.002% to 2.1% of its weight. Stainless steel differs from carbon steel by the amount of chromium present with a minimum of 11% by mass. Because of too little carbon content, stainless steel becomes quite soft, ductile and weak. Stainless steel is used where both the properties of steel and resistance to corrosion are required.

Grinding Wheel Selection

A 45 K 5 V	
Wheel Abrasive	Aluminum Oxide (Al_2O_3)
Grain size	45 (Medium)
Grade	K (Medium)
Structure	5(Dense)
Bond	V (Vitrified)
Diameter	200 mm
Width	20 mm
Bore diameter	31.75 mm
Speed	3240 m/min – 3960 m/min

Variable Constraints

- **Wheel Speed:** It is the speed of the wheel when the machine is in the full condition mode. In our project ,we are considering Aluminum Oxide (Al_2O_3). And it can be operated at the limit of 3240 m/min to 3960 m/min.
- **Work Piece Speed:** It is the speed of work piece which will be used to move it while in operation. In this work, we are considering the speed in the range of 10-20 m/min.
- **Cross-Feed Rate:** It is the feed rate of workpiece in a lateral direction to compensate the width of the work. Here we are suprassing our rate of 3.33 – 6.67 mm/pass.
- **Grinding Down Feed:** It is the feed rate of grinding wheel which reflects in terms of depth of cut. Here we are taking 0.02 – 0.2 µm as our own feed.

Process Constraints

The optimized variable constraints are contained in the upper and lower bounds of the grinding process conditions. For any problem, we can get a complete solution only by taking into account the process constraints involved in the real situation. Similarly for grinding process also we have four process constraints which affect the objection function severely. Those are:

A. Thermal Damage constraint

B. Wheel Wear Parameter constraint

C. Machine tool Stiffness constraint

D. Surface Finish constraint

OBJECTIVE FUNCTIONS

Production Cost

In the surface grinding process, the production cost consists of a cost directly related to the grinding of parts, the cost of non-productive time, and the cost of material consumption. So, the total production cost consisting of the factors mentioned above is defined by mathematical formulae as follows:

$$CT = \frac{Mc}{60 \cdot p}\left(\frac{L_w + L_e}{1000 \cdot V_w}\right)\left(\frac{b_w + b_e}{f_b}\right)\left(\frac{a_w}{a_p} + S_p + \frac{a_w \cdot b_w \cdot L_w}{\pi \cdot d_e \cdot b_s \cdot a_p \cdot G}\right) + \frac{M_c}{60 \cdot p} \cdot \left(\frac{S_d}{V_t} + t_i\right)$$
$$+ \frac{M_c \cdot t_{ch}}{60 \cdot N_t} + \frac{M_c \cdot \pi \cdot b_s \cdot d_e}{60000 \cdot p \cdot N_d \cdot L \cdot V_s} + c_s\left(\frac{a_w \cdot b_w \cdot L_w}{p \cdot G} + \frac{\pi \cdot doc \cdot b_s \cdot d_e}{p \cdot N_d}\right)$$
$$+ \frac{c_d}{p \cdot N_{td}}$$

Production Rate

Production Rate is directly related to the Rate of Removal or Material Removal Rate. It is laid as one of the important parameters of profitable production.

$$WRP = 94.4\frac{\left(1 + \frac{2\,doc}{3L}\right) L^{11/19} \left(\frac{V_w}{V_s}\right)^{3/19} V_s}{D_e^{43/304} VOL^{0.47} d_g^{5/38} R_c^{27/19}}$$

Surface Roughness

It is also one of the important parameters on which we can justify the optimum surface grinding operation. It is directly related to the value of surface finish constraint. In our work, we are practically finding the value of surface roughness for stainless steel.

Optimization Technique: Genetic Algorithm

A genetic algorithm (GA) is a search technique used in computing to find exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics. Genetic algorithms are a particular class of evolutionary algorithms (also known as evolutionary computation) that uses techniques inspired by evolutionary biology such as inheritance, mutation, selection and crossover (also called recombination).

A typical genetic algorithm required two things to be defined:

- A genetic representation of the solution domain,
- A fitness function to evaluate the solution domain.

A standard representation of the solution is as an array of bits. Arrays of other types and structures can be used in essentially the same way. The main property that makes these genetic representations convenient is that their parts are easily aligned due to their fixed size that facilitates simple crossover operation. Variable length representations may also be used, but crossover implementation is more complex in this case tree -like representations are explored in genetic programming and graph-form representations are explored in evolutionary programming. The fitness function is defined by the genetic representation and measures the quality of the represented solution. The fitness function is always problem

dependent. Once the genetic representation and the fitness function are defined, GA proceeds to initialize a population of solutions randomly, and then improve it through repetitive application of mutations, crossover, and selection operators.

‘C’ CODE

For Mutation

```
void mutate(population *new_pop_ptr);
void mutate(population *new_pop_ptr)
{
int i,*ptr,j,r;
float rand1,*rand_float_ptr;
rand1=randomperc();
new_pop_ptr->ind_ptr = &(new_pop_ptr->ind[0]);
for(j = 0;j <popsize;j++)
{
ptr= &(new_pop_ptr->ind_ptr->genes[0]);
new_pop_ptr->ind_ptr =&(new_pop_ptr->ind[j+1]);
/*Select bit */
for (i = 0;i <chrom;i++)
{
rand1 = randomperc();
/*Check whether to do mutation or not*/
if(rand1 <= pmut_b)
{
if (*ptr == 0)
*ptr =1;
else
*ptr=0;
nmut++;
}
ptr++;
}
```

```
}
return;
}
```

For Crossover

```
void crossover(population *new_pop_ptr,population *mate_pop_ptr) ;
void crossover(population *new_pop_ptr,population *mate_pop_ptr)
{
inti,j,k,l,m,n,y,mating_site,*par1,*par2,*chld1,*chld2,c;
floatrnd;
int r;
rnd=randomperc();
new_pop_ptr->ind_ptr=&(new_pop_ptr->ind[0]);
mate_pop_ptr->ind_ptr=&(mate_pop_ptr->ind[0]);
for (i = 0,y = 0,n = 0;i <popsize/2;i++)
{
new_pop_ptr->ind_ptr = &(new_pop_ptr->ind[n]);
chld1=&(new_pop_ptr->ind_ptr->genes[0]);
n = n+1;
new_pop_ptr->ind_ptr = &(new_pop_ptr->ind[n]);
chld2=&(new_pop_ptr->ind_ptr->genes[0]);
n = n+1;
mate_pop_ptr->ind_ptr = &(mate_pop_ptr->ind[y]);
par1 = &(mate_pop_ptr->ind_ptr->genes[0]);
y = y+1;
mate_pop_ptr->ind_ptr = &(mate_pop_ptr->ind[y]);
par2 = &(mate_pop_ptr->ind_ptr->genes[0]);
y = y+1;
rnd = randomperc();
if (rnd<pcross)
```

```
{
ncross++;
rnd = randomperc();
c = floor(rnd*(chrom+10));
mating_site = c;
if(mating_site>= chrom)
{
mating_site = mating_site/2;
}
for(k = 0;k <chrom;k++)
{
if(k > mating_site-1)
{
*chld1++ = *par2++;
*chld2++ = *par1++;
}
else
{
*chld1++ = *par1++;
*chld2++ = *par2++;
}
}
}
else
{
for (k = 0;k <chrom;k++)
{
*chld1++ = *par1++;
*chld2++ = *par2++;
```

```
}
}
}
return;
}
```

Experimental Analysis

We selected stainless steel as work piece for this experiment due to the wide range of applications in daily life. The abrasive wheel available for the grinding process is aluminum oxide. In this work, first we defined the ranges for variable constraints and fixed the data related to objective functions. Then we designed a fitness function which satisfies our objective functions (Production Cost + Production Rate). Then we obtained the optimized values for variable constraints from GA. We performed the surface grinding for 7 stainless steel workpieces. For all 7 components we found out the surface roughness values.

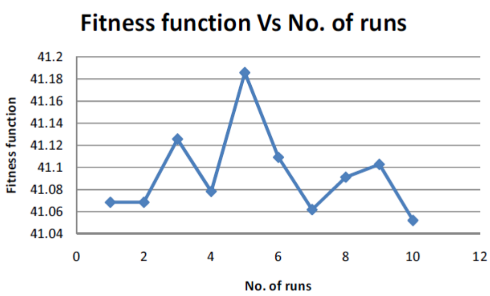
Dimensions of the workpieces are 100*20*5 mm3. We selected these dimensions based on the wheel dimensions that available for us to perform the grinding operation. As we got the workpieces of the same dimensions but with some poor surface finish initially. We performed filing operation to all the workpieces in order to get the smoother sides on course to perform the grinding as it needs some initial finish. As part of the grinding we made 10 similar workpieces of stainless steel. After performing the grinding operations for those workpieces we've calculated the surface roughness values at the Srinivasa Engineering Corporation located at Vijayawada auto Nagar, 2nd cross, and third road. Then we compared the results with the optimized component.

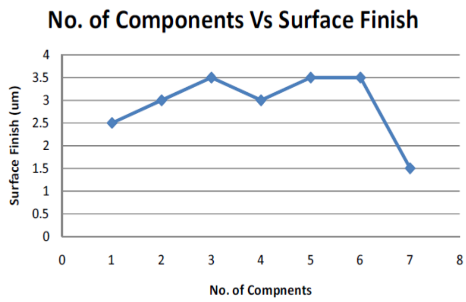
RESULTS

S.No.	Wheel Speed (m/min)	Workpiece Speed (m/min)	Cross Feed Rate (mm/pass)	Grinding Down feed (µm)	Production Cost (Rs.)	Production Rate (No./Hr.)	Surface Roughness (µm)
1.	3240	10	3	0.02	3367.1	36.4	2.5
2.	3384	12	4	0.04	1054.1	38.9	3.0
3.	3527	14	4	0.08	453.4	41.3	2.5
4.	3670	16	5	0.12	212.8	43.6	3.0
5.	3813	18	5	0.16	142.7	45.8	3.5
6.	3960	20	6	0.20	86.6	48.1	2.0
7.	3240	10	4.7	0.17	247.95	36.42	1.5*

* → least surface roughness value

Graphs





CONCLUSIONS

On successful execution of Genetic Algorithm, we got a set of values for variable constraints. These values look like picking some random points in solution space. When finding the surface roughness for the components which are ground with manually selected parameter values, its R_a value is less than that of the operation with GA parameter values. From this, we strongly recommend going for Genetic Algorithm before we go for manual experimentation. We also observed that the production cost is decreasing drastically as the number of components is increasing. From this, we concluded that manual surface grinding operation should be preferable when we try for a batch production of components. This is directly related to the production rate, which is indirectly proportional to production cost. So if we want to perform a surface grinding operation, we should go for a batch production.

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